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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) We have studied random, Fibonacci and Thue-Morse GaAs-based superlattices using Raman scattering and other optical techniques. The non-resonant Raman data provides information on Fourier components of the modulation while resonant results reveal dips associated with gaps in the phonon spectrum. The latter have been explained in terms of a model showing that phonons with wavevector close to the zone edge and zone centers avoid the surface.		

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Electronic Properties of Quasiperiodic GaAs-(Al,Ga)As Heterostructures

FINAL REPORT

Period: June 1, 1989 - August 31, 1989

A. Nonperiodic GaAs-AlAs Superlattices.

Nonperiodic superlattices offer interesting possibilities for experimental studies of unusual physical phenomena.¹ During the course of our research, we have studied several types of nonperiodic superlattices: random, Fibonacci, and Thue-Morse. The interest in random superlattices focuses on the problem of Anderson localization.² Fibonacci superlattices are 1D analogs of quasicrystals with wave behavior characterized by a self-similar hierarchy of gaps and critical (or chaotic) eigenstates.¹ Structures based on *automatic* sequences have recently been considered in the literature.³ Thue-Morse superlattices¹ belong to this group.

Nonperiodicity does not necessarily imply the lack of a deterministic order (as in the case of a random system). Fibonacci and Thue-Morse superlattices are produced following well defined rules.¹ Fibonacci superlattices are examples of quasiperiodic (or incommensurate) structures. The major problem in fabricating such structures in the past has been the fact that simple incommensurate modulations require increasingly larger layer thicknesses to approach the irrational limit. Layer deposition in sequences generated by special production rules provides a solution to this problem.¹ Superlattices grown according to these sequences show a degree of quasiperiodicity that is determined not by the width of the layers (which is arbitrary), but by the thickness of the samples.¹

We have investigated these nonperiodic systems using several methods of optical spectroscopy: photoluminescence, optical reflectivity, optical absorption, and Raman scattering. Our results are described in detail in the publications. The most fruitful of these techniques has been Raman scattering by acoustic phonons. The non-resonant

Raman spectra of these systems provides information about the structure of the superlattice which complements the information obtained by X-ray scattering.⁴ The resonant Raman spectra resembles a weighted density of states which provides information about the gaps in the phonon spectrum. This information can not possibly be obtained through other techniques.⁴

B. Surface effects in periodic GaAs-AlAs Superlattices.

The simplest superlattice to study which does not have translational symmetry is a semi-infinite or finite periodic superlattice. Here, the translational symmetry is broken by the presence of a surface (or two surfaces). This has two major effects on the elementary excitations of the system. First, it allows for the existence of states localized at the surface with energy in the gap of the infinite system. Second, all wave functions are standing waves since they are required to satisfy boundary conditions at the surface. This second effect leads to the existence of surface avoiding wave functions for states with momenta near the zone edge or zone center of the superlattice.⁶ We have found that the amplitude of acoustic phonons with momenta $q = n\pi d^{-1} \pm \epsilon$ is vanishingly small in a region proportional to ϵ^{-1} from the surface (n is an integer and d is the superlattice period). Accordingly, the matrix element describing coupling of phonons to electronic excitations localized at the surface shows pronounced dips in the vicinity of the gaps in the phonon density of states. We conjecture that dips in the Raman spectra, observed by us in nonperiodic superlattices,⁴ and previously by others in finite periodic superlattices,⁵ arise from this effect, i.e., that they reflect contributions of surface electronic states to the scattering. We have performed numerical calculations of the Raman spectra of several systems which compare favorably with experimental data.

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Publications

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A. Journals

1. "Raman Scattering by Acoustic Phonons in Fibonacci GaAs-AlAs Superlattices",
K. Bajema and R. Merlin, Phys. Rev. B36, 4555 (1987).

B. Conference Proceedings

1. "Raman Scattering by Acoustic Phonons and Structural Properties of Fibonacci, Thue-Morse and Random Superlattices", presented at the Third International Conference on Modulated Semiconductor Structure, Montpellier, 1987, R. Merlin, K. Bajema, J. Nagle and K. Ploog, J. Phys. 48, C-5 503 (1987).
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